§41. Hierarchy-renormalized Simulation Model

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In order to develop a predictive simulation code system in three-dimensional toroidal magnetic configuration like LHD, a hierarchy-renormalized simulation model is proposed under domestic and international collaborations with universities and institutes.

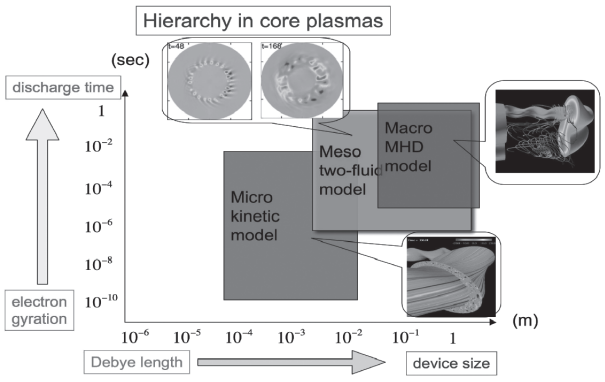
The hierarchy-renormalized simulation model in three-dimensional toroidal magnetic configurations consists of a hierarchy-integrated simulation approach and a hierarchy-extended simulation approach.

The hierarchy-integrated simulation approach, which is mainly based on a transport simulation combining various simplified models describing physical processes in different hierarchies, is suitable for investigating whole temporal behavior of experimentally observed macroscopic physics quantities. The hierarchy-integrated simulation code is being developed based on the integrated modeling code for tokamak plasmas; TASK [1], developed in Kyoto University, and is called TASK/3D.

On the other hand, the hierarchy-extended simulation approach, which includes fluid core plasma description, kinetic core plasma description, and peripheral fluid/kinetic description, is focused on the description of mutual interaction among neighboring hierarchies in a more rigorous way. In fluid core plasma description, MHD nonlinear dynamics is investigated by using MINOS code with high accuracy, interaction between high-energy particles and background MHD modes is examined by using MEGA code consisting of the drift-kinetic energetic particles and background MHD fluid, multiple-phase states consisting of gas, liquid, and solid phases related to the ablation of a solid pellet are analyzed by using CAP code, and interactions among microscopic turbulence, macroscopic MHD modes, and meso- scale zonal flows is examined based on a two-fluid simulation model. In the kinetic core plasma description, various types of gyro-kinetic Vlasov code; GKV is developed and used for performing ITG and ETG linear and nonlinear local analyses in both two- and three-dimensional toroidal magnetic configurations. In the figure, a macro-hierarchy expressed by MHD model, a meso-hierarchy expressed by the two-fluid model, and a micro-hierarchy expressed by the distribution function are shown together with typical hierarchy-extended simulation results. In peripheral fluid/ kinetic description, analyses of various phenomena such as dust plasma, plasma-wall interaction, impurity transport, and behavior of neutrals are performed. Moreover, some theoretical works such as fluid closure, two-fluid equilibrium and nonlinear equation models are done in order to make innovative simulation models.

The hierarchy-renormalized simulation model is constructed by renormalizing the results of the hierarchy-extended simulation model, as a comprehensive theoretical model, or numerical data, or module into the hierarchy-integrated simulation model.

In a short term, predictive simulations based on the hierarchy-integrated simulation model; TASK/3D will be performed for the deuterium experiments being planned in LHD; while, in a long term, the hierarchy-renormalized simulation research will be done, leading to the LHD Numerical Test Reactor.



[1] A. Fukuyama et al., Proc. of 20th IAEA Fusion Energy Conf. (Villamoura, Portugal, 2004) IAEA-CSP-25/CD/TH/P2-3.